

METHOD FOR ESTIMATING METHANE EMISSIONS FROM COAL MINING

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DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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1

INTRODUCTION

The purposes of the preferred methods guidelines are to describe emissions estimation techniques for greenhouse gas sources in a clear and unambiguous manner and to provide concise example calculations to aid in the preparation of emission inventories. This chapter describes the procedures and recommended approaches for estimating methane emissions from coal mining.

Section 2 of this chapter provides a source category description. Section 3 gives an overview of the methodology for estimating methane emissions from coal mines. Section 4 describes the preferred estimation methodology while Section 5 is a placeholder section for alternative emission estimation techniques that may be added in the future. Quality assurance and quality control procedures are described in Section 6. References used in developing this chapter are listed in Section 7.

2

SOURCE CATEGORY DESCRIPTION

2.1 EMISSION SOURCES

There are three sources of methane emissions from coal mining: emissions from underground mining, emissions from surface mining, and emissions from post-mining activities. Emissions from post-mining activities may be further subdivided into emissions from underground mined coal and emissions from surface mined coal. Each of these emission sources is described in more detail below.

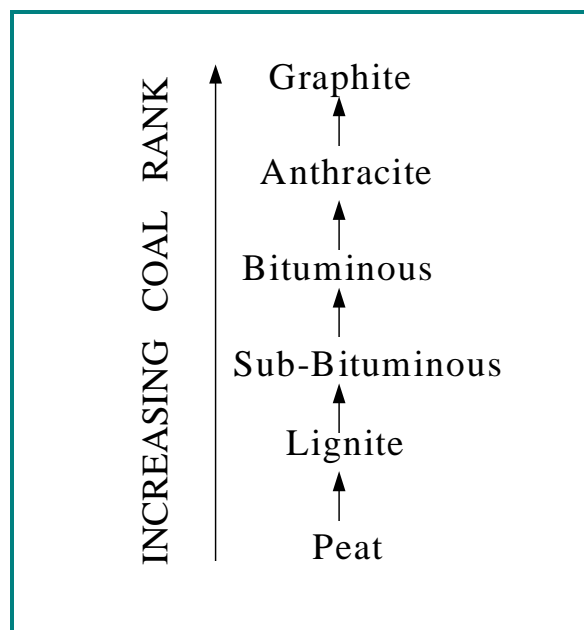
Because methane is a safety hazard in underground mines, substantial research has been undertaken to determine how to predict and control methane emissions in mine working areas. This research makes possible fairly accurate estimates of the quantity of methane emitted from underground mines. Similar research has not yet been undertaken for surface mines, which emit smaller quantities of methane and do not have similar safety issues associated with them.

Overview of Coalbed Methane Production¹

How Coalbed Methane Is Produced, Stored and Released

Coal is formed over millions of years as organic matter is transformed by complex processes known as "coalification." Coalification is controlled by chemical and physical processes, temperature, pressure, and geologic history. Differing levels of coalification produce different "ranks" of coal, as shown in Exhibit 4.2-1.² Coalification results in both physical and chemical changes, including methane generation. Other byproducts of the coalification process are water and carbon dioxide.

Exhibit 4.2-1: Stages in Coalification



¹ This overview section is adapted from the coal mining chapter of the EPA Report to Congress entitled *Anthropogenic Methane Emissions in the United States: Estimates for 1990*.

² Higher rank coals contain more fixed carbon, less volatile matter, and less moisture.

The amount of methane produced increases throughout the coalification process. Thus, higher ranked coals tend to contain more methane than lower ranked coals.

How Methane is Stored in Coal

Methane is stored in the coal itself and can also be contained in the surrounding strata. Large amounts of methane can be stored within the microstructure of coal. Methane storage in coalbeds, mainly by adsorption onto internal coal surfaces, is a function of rank and pressure.³ In general, coals of increasing rank have higher methane storage capacities. In addition, storage capacity increases almost linearly with increasing pressure, which in turn is a function of depth of the coal seam. Therefore, among coal seams of the same rank, deeper seams store more methane.

Even high rank coals cannot store all of the methane generated during coalification, however. The highest gas contents measured for anthracite coal in the United States, for example, are only 10 to 12 percent of the total amount of methane that was generated during coalification. The rest of the methane migrated out of the coal over time. Some of this gas remains stored in the surrounding strata, and some has likely been emitted to the atmosphere as a result of natural processes.

Methane is released when pressure within a coalbed is reduced, either through mining or through natural erosion or faulting. Methane will migrate through coal from zones of higher concentration to zones of lower concentration until it intersects a pathway, such as a joint system or fracture. The size, spacing, and continuity of such pathways determine the permeability of the coal and control the flow of methane through the coal to the surface or the mine workings.

As pressure is reduced during mining, methane is liberated from the seam being mined and from surrounding strata. In addition to the rank and depth of the coal, the amount of disturbance to the surrounding

During mining, methane is emitted from the mined coal seam as well as from surrounding coal seams and/or gas-bearing strata.

strata as a result of mining activities will also determine the quantity of methane liberated. The amount of methane liberated by mining activities can exceed the amount of gas contained in the mined coal by as much as 3 to 9 times (Kissell et al. 1973).

U.S. Mining Techniques

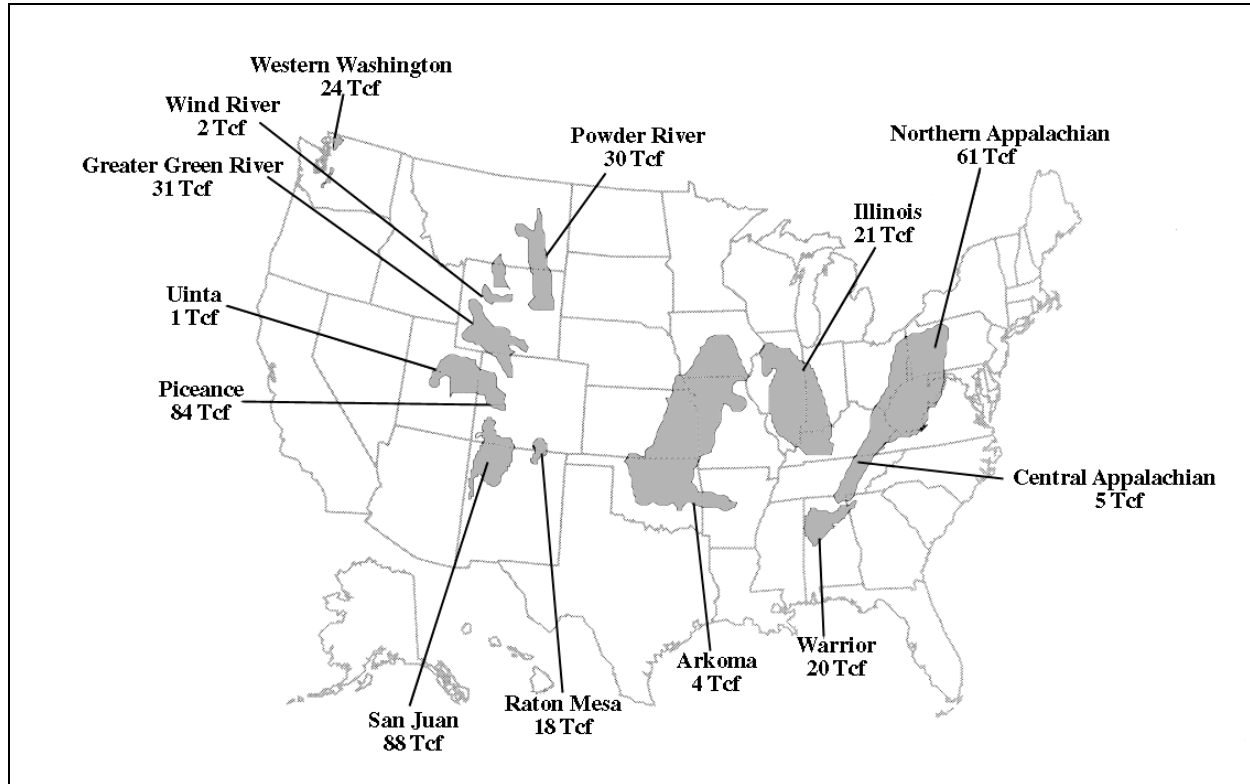
Coal is produced in the United States in underground and surface mines. Coalbeds shallower than about 200 feet are generally mined from the surface, while deeper coalbeds are usually mined by underground methods. As mentioned earlier, underground mines contain more methane than surface mines; thus, underground mines liberate more methane than surface mines.

³ Adsorption is the adhesion of an extremely thin layer of molecules to the surfaces of solid bodies with which they are in contact.

The major U.S. coal basins are shown in Exhibit 4.2-2. In general, coal in the Western basins is mined using surface methods, while most Eastern basin coals are mined using underground methods.

Exhibit 4.2-2: U.S. Coal Basins and Coalbed Methane Resources

Note: not all coal basins support active coal mines. Tcf = 10^{12} cubic feet.



2.1.1 Underground Mining

Coal mined at underground mines accounted for about 40 percent of total U.S. coal production in 1990, and the proportion of underground to surface production has remained relatively constant from 1990 through 1997. Most underground mining occurs in the Eastern United States, primarily in the Northern and Central Appalachian Basins (which are located in Pennsylvania, Virginia, West Virginia, Ohio, and Kentucky), and in the Black Warrior Basin of Alabama.

U.S. underground mines range from less than 1,000 feet deep to over 2,000 feet deep. Although methane may be emitted during construction of underground mines, the bulk of the methane is emitted during coal extraction, when controlled blasts create pathways for the methane to move into the mine workings from unmined areas of the target coal seam and other strata.

Two underground mining methods are commonly used in the United States: room-and-pillar mining and longwall mining. The choice between these methods depends on geologic factors

Longwall mining liberates more methane than room-and-pillar mining. Most of the gassiest underground mines in the U.S. use longwall mining methods.

(such as depth, terrain, and width of coalbed) and economic factors, such as equipment cost. Room-and-pillar mining is the most common underground mining technique in the United States, although the number of longwall mines is growing. Mechanized longwall mining was introduced in the U.S. during the 1960s, and today there are almost 70 longwall mines in operation (Reid, 1997). Longwall mines are typically bigger and deeper than room-and-pillar mines. They are also more expensive to equip and operate, but generally have higher coal production rates. The higher production, coupled with the more extensive caving typically associated with longwall mines, tends to result in higher methane emissions.

Methane Management Systems for Underground Mining

Methane is a serious safety threat in underground coal mines because it is highly explosive in atmospheric concentrations of 5 to 15 percent. The U.S. Mine Safety and Health Administration (MSHA), an agency of the U.S. Department of Labor, requires close monitoring of methane levels to ensure that methane concentrations in underground mines are kept below explosive levels. In mine entries used by personnel, methane levels cannot exceed 1 percent, and in certain designated areas of the mine not frequented by mine personnel, methane levels cannot exceed 2 percent. If these concentrations are exceeded, MSHA requires that coal production cease until methane concentrations are reduced to acceptable levels.

There are two methods for controlling methane in underground mines: use of ventilation systems and use of degasification systems. Ventilation systems are employed at all underground mines.⁴ The decision to use a degasification system is based primarily on safety factors, but may also be greatly influenced by the opportunity to sell or

Approximately 21 gassy U.S. underground mines use degasification systems in addition to ventilation to ensure safe mining conditions. These systems produce high quality methane that can be sold to a pipeline, used to generate electricity, or used in a number of other applications.

use the recovered gas. In especially gassy mines, the use of a ventilation system alone may be inadequate to degasify a mine so that it meets federal regulations with regard to maximum methane concentrations. In such cases, a degasification system may be installed to help degasify the mine either prior to, during, or after mining. The methane recovered from these systems is usually of sufficient quality that the methane can be sold to a pipeline or used for any number of applications, including electricity generation. In 1996, there were only 21 underground mines with degasification systems, out of more than 900 underground mines in the U.S. In addition to the potential economic benefits associated with the sale of this gas, such projects have the added advantage of reducing atmospheric methane emissions.

The various methods of controlling methane in underground mines are summarized in Exhibit 4.2-3.

⁴ Only those underground mines with detectable methane emissions are surveyed by the Mine Safety and Health Administration (MSHA). Detectable emissions are defined by MSHA as methane concentrations at the mine entrance greater than 50 parts per million methane. Readings below this threshold are considered non-detectable.

Exhibit 4.2-3: Approaches for Methane Control at Underground Mines	
Method	Description
Ventilation	<ul style="list-style-type: none"> • Universal method to dilute and exhaust methane to the atmosphere. • Sufficient, in many mines, to maintain safe mining conditions. • In the gassiest mines, supplemental degasification systems may be required.
Degasification Techniques:	
Vertical Wells in Advance of Mining	<ul style="list-style-type: none"> • Remove methane before mining operations begin. • Can recover large amounts of pipeline quality methane. • Can produce methane from multiple coal seams.
Gob Wells	<ul style="list-style-type: none"> • Surface wells used in longwall mining to remove methane from portions of overlying strata ("gob areas") allowed to collapse after mining. • Can recover large amounts of methane (quality of recovered methane varies).
Horizontal Boreholes	<ul style="list-style-type: none"> • Drilled from inside the mine to degasify the coal seam being mined, either years in advance of mining or shortly before mining. • Methane is removed through an in-mine piping system. • Can recover pipeline quality gas.
Cross-Measure Boreholes	<ul style="list-style-type: none"> • Drilled from inside the mine to degasify the overlying or underlying coal and rock strata. • Methane is removed through an in-mine piping system. • Gas can become contaminated with mine air during production. • Used infrequently in the U.S.
Source: U.S. EPA 1997b	

2.1.2 Surface Mining

Surface mining, also called strip mining, is used to mine coal at shallow depths. In essence, it involves large scale earth-moving; the overburden on top of the coal is excavated followed by removal of the coal. Coal recovery rates at surface mines can exceed 90 percent.

In 1990, 603 million tons of coal was produced at surface mines, mostly in sub-bituminous and lignite mines in the Western United States. This represented about 60 percent of total U.S. coal production. The largest and fastest growing U.S. surface mining region is the Powder River Basin of Wyoming and Montana. Surface mines are also located in the lignite fields of North Dakota, South Dakota, and Montana, and in the Eastern bituminous coal basin in Illinois, Indiana, and western Kentucky.

Methane emissions from surface mines are highly uncertain. Available information indicates that emissions per ton of coal mined are low because these coals do not contain much methane.

2.1.3 Post-Mining

Not all of the methane contained in coal is released during mining. Some methane remains in the coal after it is removed from the mine and can be emitted as the coal is transported, processed, and stored. Depending on the characteristics of the coal and the way it is handled after leaving the mine, the amount of methane released during post-mining activities can be significant and can continue for weeks or months. The greatest releases occur when coal is crushed, sized, and dried in preparation for industrial or utility uses (U.S. EPA, 1990).

2.2 FACTORS INFLUENCING EMISSIONS

Of the emission sources described above, emissions from underground mining are by far the largest contributor to methane emissions from coal mining. In the U.S., underground mining emissions account for about 70 percent of the total methane emitted from coal mines in any given year. Emissions from surface mines and post-mining activities account for the remainder. Thus, the factors that have the greatest impact on emissions are factors related to underground mining.

As discussed earlier, the amount of methane generated during coal mining depends on the type of mine, gas content of the coal seam, mining methods, and other factors such as moisture. Emissions are also affected by the amount of coal mined; the greater the quantity of coal mined the greater the amount of methane released. High ranks of coal contain more methane than low ranks. Between two coal seams with the same rank, the deeper seam will contain more methane, because it is under more pressure. The amount of methane emitted depends not only on the amount generated, but also on whether a degasification system with methane recovery is used. Surface seams have the lowest methane content and do not support the use of degasification systems.

OVERVIEW OF AVAILABLE METHODS

A three-part approach is used to estimate methane emissions from coal mining. Emissions from underground mining are estimated on a mine-specific basis; emissions from surface mining and post-mining activities are estimated using a basin-specific approach.

Total methane liberated from underground mining is comprised of methane liberated from ventilation systems and from degasification systems. Total methane liberated from underground mines is adjusted downwards to account for methane that is recovered and used for energy purposes. The resulting value is referred to as methane emitted from underground mines.

Estimating methane emitted from surface mining involves multiplying the quantity of surface-mined coal from each coal basin in a state by the appropriate emission factor for that basin. A basin-specific approach is also used to determine post-mining emissions.

The total methane emitted from coal mines is the sum of (1) methane emitted from underground coal mines plus (2) methane

Methods for developing greenhouse gas inventories are continuously evolving and improving. The methods presented in this volume represent the work of the EIIP Greenhouse Gas Committee in 1998 and early 1999. This volume takes into account the guidance and information available at the time on inventory methods, specifically, U.S. EPA's *State Workbook: Methodologies for Estimating Greenhouse Gas Emissions* (U.S.EPA 1998a), volumes 1-3 of the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997), and the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 1996* (U.S. EPA 1998b).

There have been several recent developments in inventory methodologies, including:

- Publication of EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 1997* (U.S. EPA 1999) and completion of the draft inventory for 1990 – 1998. These documents will include methodological improvements for several sources and present the U.S. methodologies in a more transparent manner than in previous inventories;
- Initiation of several new programs with industry, which provide new data and information that can be applied to current methods or applied to more accurate and reliable methods (so called "higher tier methods" by IPCC); and
- The IPCC Greenhouse Gas Inventory Program's upcoming report on Good Practice in Inventory Management, which develops good practice guidance for the implementation of the 1996 IPCC Guidelines. The report will be published by the IPCC in May 2000.

Note that the EIIP Greenhouse Gas Committee has not incorporated these developments into this version of the volume. Given the rapid pace of change in the area of greenhouse gas inventory methodologies, users of this document are encouraged to seek the most up-to-date information from EPA and the IPCC when developing inventories. EPA intends to provide periodic updates to the EIIP chapters to reflect important methodological developments. To determine whether an updated version of this chapter is available, please check the EIIP site at <http://www.epa.gov/ttn/chief/eiip/techrep.htm#green>.

emitted from surface mines plus (3) methane emitted from post-mining activities (see Exhibit 4.3-1). This approach is described in detail in the next chapter.

Exhibit 4.3-1: Components of Methane Emissions from Coal Mining

$$\begin{aligned} &\text{Methane Emissions from Coal Mining} = \\ &\text{Underground Mine Emissions (Underground Methane Liberated}^1\text{ – Methane Used)} \\ &\quad + \\ &\quad \text{Surface Mine Emissions} \\ &\quad + \\ &\quad \text{Post-Mining Emissions (from Underground- and Surface-Mined Coal)} \end{aligned}$$

Note: ¹ Underground Methane Liberated is the sum of ventilation emissions and degasification emissions.

The methods described here are the Intergovernmental Panel on Climate Change (IPCC) “Tier 2” methods presented in *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 1997). These methods are also used in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997* (U.S. EPA 1999).

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PREFERRED METHOD FOR ESTIMATING EMISSIONS

Methane liberated during coal mining may originate from underground mine ventilation/degasification systems, from surface mines, or from post-mining activities. Methane recovered from an underground mine by a degasification system may be either vented or used for energy recovery. To account for all coal mine methane emissions to the atmosphere, the following steps are required:

- 1) obtain required data;
- 2) estimate methane liberated from underground mines in the state;
- 3) determine the amount of methane from underground mines that is recovered and used;
- 4) estimate methane emissions from surface mines;
- 5) estimate methane emissions from post-mining activities;
- 6) calculate state methane emissions from coal mining by adding the difference between (2) and (3) to the sum of (4) and (5); and
- 7) convert the result to (6) to units of metric tons of carbon equivalent (MTCE).

Step (1): Obtain Required Data

- *Required Data.* To estimate underground mining emissions, the required data are the ventilation emissions for each underground mine in the state. In addition, for those states that have mines with degasification systems, the following data are needed: (1) a list of mines in the state with degasification systems and (2) the mine-by-mine amount of methane recovered by degasification systems that is used for energy recovery. To estimate surface mining emissions and post-mining emissions (from both underground- and surface-mined coal), data on the state's annual coal production, grouped by underground and surface production, are needed.
- *Data Sources.* The US EPA Office of Air and Radiation, Methane Energy Branch (OAR/MEB) produces estimates of methane emissions from coal mining for EPA's annual greenhouse gas inventory (e.g., EPA 1998). Appendix D of the EPA inventory lists a complete estimate of methane emissions from coal mining activities for each state, and can be found at <http://www.epa.gov/globalwarming>. For underground mines, these estimates are based on mine by mine information on ventilation and degasification emissions provided by the Mine Safety Health Administration (MSHA). Surface and post-mining emissions are based on and coal production data published by the U.S. Department of Energy. States may wish to use the estimates provided in Appendix D for their state inventory. Alternatively, if states choose to collect the information themselves, they may obtain this information by calling the EPA/MEB at 202-564-9110. Ventilation emissions data and a list of mines with active degasification systems may also be obtained from MSHA district offices. A complete listing of MSHA district offices can be found at <http://www.msha.gov>. Coal production data

may be available from a state coal agency; alternatively, these data are available from the U.S. Department of Energy publication *Coal Industry Annual* (e.g., U.S. DOE/EIA 1997), which can be accessed at <http://www.eia.doe.gov/coal>.

- *Units for Reporting Data.* Methane emissions should be expressed in cubic feet; coal production values should be expressed in short tons.

Step (2): Estimate Methane Liberated from Underground Mines

Methane liberated from underground mining consists of methane emitted by ventilation systems and methane removed by degasification systems.

Measured Ventilation Emissions from Underground Mines. For those states with no mines with degasification systems, sum the MSHA data on methane emissions from ventilation systems for all underground mines in the state. This will be the estimate of methane liberated from underground mines for the state. For all other states see below.

Degasification System Emissions (Applies only to states that have such systems). There are two ways to determine degasification system emissions.

1. A mine operator may be able to provide information on the amount of methane being captured by the mine's degasification systems. If the recovered methane is not used, then degasification system emissions equal the amount of methane recovered from the mine. If some or all of the recovered methane is used, this portion is deducted in Step (3).
2. Alternatively, an estimate of recovery system efficiency can be used to estimate degasification system emissions. The recovery efficiency is a measure of the amount of methane that is recovered and used relative to the amount of methane that would have been vented if there were no degasification system in place. If mine-specific estimates of efficiency are not available a default value of 40 percent may be used (EPA 1997b). The example below shows how the recovery efficiency can be used to estimate the methane liberated from degasification system emissions.

Example

In 1996, average methane emissions from underground mine ventilation systems in West Virginia were 53.2 million cubic feet of methane per day. Six of the mines in West Virginia had degasification systems. One of those mines had ventilation emissions of 10.7 million cubic feet per day (mmcf/d), or 3,906 million cubic feet per year (mmcfy); its degasification system had a known recovery efficiency of 40 percent. According to published MSHA data, total ventilation emissions from the other five mines with degasification systems were 26.3 mmcf/d, or 9,600 mmcfy. No recovery efficiencies are given for these remaining five mines. Total methane liberated from underground mines in West Virginia for 1996 is equal to the flows through the ventilation systems plus flows through the degasification systems.

Total emissions from underground mines equals the total methane liberated from ventilation systems plus the total methane liberated from degasification systems.

Total methane liberated from ventilation systems = 53,200,000 cubic feet per day × 365 days per year
= **19,400 mmcfy.**

Total methane liberated from degasification systems. To calculate this quantity, recovery efficiencies are used.

The Pinnacle No. 50 Mine. If 40% of the methane is recovered and used from the mine's degasification system, then 60% is emitted through the mine's ventilation system since the two systems work together to degasify the mine.

Total methane liberated from Pinnacle No. 50 mine = Ventilation Emissions/Ventilation % (or 1-Recovery Efficiency) = $10.7 \text{ mmcf}/0.60 = 17.8 \text{ mmcf}$.

Total methane liberated from degasification system = Total methane liberated – Total methane liberated from ventilation system = $17.83 - 10.7 = 7.13 \text{ mmcf}$ or 2,600 mmcfy.

The Other Five Underground Mines. Since no recovery efficiency is given, assume default value of 40%. Total methane liberated from other mines = $26.3 \text{ mmcf}/0.60 = 43.8 \text{ mmcf}$.

Total methane liberated from degasification system = Total methane liberated – Total methane liberated from ventilation system = $43.8 - 26.3 = 17.53 \text{ mmcf}$ or 6,400 mmcfy.

Total Methane Liberated from Underground Mines in West Virginia = (19,400 + 2,600 + 6,400) mmcfy = 28,400 mmcfy.

Step (3): Obtain Data on the Amount of Methane Recovered by Degasification Systems that is Used for Energy Recovery

As noted under step 1, US EPA OAR/MEB collects information to generate estimates of methane emissions from coal mining for EPA's annual greenhouse gas inventory. This information includes the quantity of methane recovered by degasification systems that is used for energy recovery in each state. These data will eventually be accessible on EPA's website; meanwhile, states wishing to obtain this information can call the EPA/MEB at 202-564-9110.

In 1996, 776 million cubic feet of methane were recovered by degasification systems in West Virginia and used for energy recovery.

Step (4): Estimate Methane Emitted from Surface Mines

Methane emissions from surface mines are estimated by multiplying the state's surface coal production in each coal basin by an emission factor based on the in-situ methane content for the surface coal found in each coal basin. A state's annual surface coal production can be found in *Coal Industry Annual* (e.g., U.S. DOE/EIA 1997). The emission factor, which is given on a basin-specific basis and can be found in Exhibit 4.4-1, accounts for methane liberated from the coal itself and from surrounding strata. Two states—Kentucky and West Virginia—span more than one coal basin. For these two states, emissions are determined by county-level surface coal production. The counties and their associated basins are listed below:

Kentucky

- **Western Kentucky Counties (in the Illinois Basin):** Butler, Caldwell, Crittendon, Christian, Daviess, Edmonston, Grayson, Hancock, Henderson, Hopkins, Logan, McLean, Muhlenberg, Ohio, Todd, Union, Webster.
- **Eastern Kentucky Counties (in the Central Appalachian Basin)** All other coal-producing counties in Kentucky are eastern counties.

West Virginia

- **Northern Counties (in the Northern Appalachian Basin):** Barbour, Braxton, Brooke, Gilmer, Grant, Harrison, Lewis, Marion, Marshall, Mineral, Monongalia, Ohio, Pendelton, Preston, Randolph, Taylor, Tucker, Upshur, Webster.
- **Southern Counties (in the Central Appalachian Basin):** All other coal-producing counties in West Virginia are southern counties.

Total methane emissions from surface mines = Total surface coal production in state × Basin-specific methane emission co-efficient for coal produced from surface mines

Exhibit 4.4-1: Methane Emission Coefficients for Coal Produced from Surface Mines	
Basin	Emission Coefficient (cubic feet methane/ton of coal mined)
Central Appalachian Basin: eastern Kentucky, Tennessee, Virginia, southern West Virginia	98.6
Northern Appalachian Basin: Maryland, Ohio, Pennsylvania, northern West Virginia	98.6
Black Warrior Basin: Alabama	98.6
Rockies and Southwest Basins: Colorado, New Mexico, Utah	30.6
Illinois Basin: Illinois, Indiana, western Kentucky	78
All Other States:	6.4
Source: U.S. EPA 1997a.	

Example

According to DOE/EIA's *Coal Industry Annual 1996* (U.S. DOE/EIA 1997), in 1996 West Virginia's northern counties produced 5,635,000 short tons of coal from surface mines, and its southern counties produced 49,213,000 short tons of coal from surface mines.

West Virginia's northern counties:

5,635,000 short tons × 98.6 cubic feet/ton = 556,000,000 cubic feet methane emitted

West Virginia's southern counties:

49,213,000 short tons × 98.6 cubic feet/ton = 4,850,000,000 cubic feet methane emitted

Total methane emissions from surface mines in West Virginia:

(556,000,000 + 4,850,000,000) cubic feet = 5,410,000,000 cubic feet methane emitted

Step (5): Estimate Methane Emitted during Post-Mining Activities

The U.S. EPA estimates that methane emitted during post-mining activities, such as transportation and handling of coal, equals 33 percent of the in-situ methane content for the coal

(U.S. EPA 1993). EPA has used this formula to develop post-mining emission factors, as shown in Exhibit 4.4-2. Post-mining emissions must be calculated separately for underground- and surface- mined coals.

Total post-mining methane emissions = (Total coal production from surface mines in state × Basin-specific post-mining methane emission coefficient for surface-mined coal) + (Total coal production from underground mines in state × Basin-specific post-mining methane emission coefficient for underground-mined coal)

Exhibit 4.4-2		
Post-Mining Methane Emissions Coefficients for Underground- and Surface-Mined Coal		
	Underground Mines (cf/ton)	Surface Mines (cf/ton)
Central Appalachian Basin: Eastern Kentucky, Tennessee, Virginia, southern West Virginia	107.5	16.0
Northern Appalachian Basin: Maryland, Ohio, Pennsylvania, northern West Virginia	55.8	16.0
Black Warrior Basin: Alabama	103.4	16.0
Rockies and Southwest Basins: Colorado, New Mexico, Utah	73.4	5.0
Illinois Basin: Illinois, Indiana, western Kentucky	18.6	12.7
All Other States:	13.5	1.0
Source: U.S. EPA, 1997a		

Step (6): Calculate Total Methane Emissions from Coal Mining

Example According to DOE/EIA's Coal Industry Annual 1996 (U.S. DOE/EIA 1997), in 1996 West Virginia's northern and southern counties produced 40,244,000 short tons and 75,342,000 short tons, respectively from underground mines. The state's surface mines produced 5,635,000 short tons and 49,213,000 short tons, from the northern and southern counties, respectively. What were the post-mining emissions from coal mines in West Virginia in 1996?

Post-Mining Methane Emissions from Surface-Mined Coal:

Northern Counties

= 5,635,000 short tons × 16 cubic feet/ton = 90,000,000 cubic feet

Southern Counties

= 49,213,000 short tons × 16 cubic feet/ton = 790,000,000 cubic feet

Total = 880,000,000 cubic feet

Post-Mining Methane Emissions from Underground-Mined Coal:

Northern Counties

= 40,244,000 short tons × 55.8 cubic feet/ton = 2,250,000,000 cubic feet

Southern Counties

= 75,342,000 short tons × 107.5 cubic feet/ton = 8,100,000,000 cubic feet

Total = 10,300,000,000 cubic feet

Total Post-Mining Methane Emissions in West Virginia:

= 880,000,000 cubic feet + 10,300,000,000 cubic feet

= 11,200,000,000 cubic feet

Total methane emissions from coal mining are calculated by summing emissions from (1) underground mines (underground methane liberated minus any methane recovered and used), (2) surface mines, and (3) post-mining activities.

Total Methane Emissions from Coal Mining = (Total methane liberated from underground mines – Methane recovered by degasification systems that is used for energy recovery) + Total methane emissions from surface mines + Total methane emissions from post-mining activities (underground and surface)

Example

For the state of West Virginia, total methane emissions from coal mines in 1996 are calculated as follows:

Total methane emissions from coal mining = (Total methane liberated from underground mines – Methane recovered by degasification systems that is used) + Total methane emissions from surface mines + Total methane emissions from post-mining activity.

Using figures derived in earlier parts of this section,
Total Methane Emissions from Coal Mining = (28,400 mmcfy methane liberated from underground mines - 776 mmcfy methane recovered by degasification systems used for energy recovery) + 5,400 mmcfy methane emissions from surface mines + 11,200 mmcfy methane emissions during post-mining activities

= 44,200 million cubic feet of methane

Step (7): Convert the Result to Units of MTCE

The resulting value is then converted to MTCE by first converting cubic feet to grams by multiplying by 19.2 grams/cubic foot of methane. Next, convert from grams to metric tons by multiplying by 1 metric ton/1,000,000 gm. Finally, multiply by 21 (the global warming potential of methane) to obtain methane emissions in metric tons of carbon dioxide equivalent and then multiply by 12/44 (the ratio of the atomic weight of carbon to the molecular weight of CO₂) to obtain metric tons of carbon equivalent.

Convert to MTCE

44,200,000,000 cubic feet of CH₄ × 19.2 g/cubic foot CH₄ × 1 metric ton/1,000,000 g × 12/44 × 21

= **4,870,000 MTCE**

5

ALTERNATE METHODS FOR ESTIMATING EMISSIONS

No alternate methods have yet been approved by the Greenhouse Gas Committee of the Emission Inventory Improvement Program.

QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance (QA) and quality control (QC) are essential elements in producing high quality emission estimates and should be included in all methods to estimate emissions. QA/QC of emissions estimates are accomplished through a set of procedures that ensure the quality and reliability of data collection and processing. These procedures include the use of appropriate emission estimation methods, reasonable assumptions, data reliability checks, and accuracy/logic checks of calculations. Volume VI of this series, *Quality Assurance Procedures*, describes methods and tools for performing these procedures.

There is uncertainty associated with each of the emission subsources. This section describes the origin of the uncertainty and provides uncertainty estimates, based on an analysis of uncertainty performed by US EPA's Methane Energy Branch. That analysis was based on the use of expert judgment on the quality of the data, used as inputs to a Monte Carlo analysis.

Underground ventilation systems. Methane emissions from ventilation systems are based on quarterly measurements taken by MSHA at individual mines. Because the emission estimates are based on actual measurements, the uncertainty associated with the estimate is assumed to be low. The main uncertainty associated with the ventilation estimates is that they are based on quarterly measurements. Accordingly, to the extent that the average of the four quarterly measurements are not representative of the true annual average at a given mine, average emissions at a particular mine may be over- or under-estimated. In addition to possible uncertainties associated with using quarterly measurements, there are some limited uncertainties associated with the potential for measurement and reporting errors. Uncertainty in this sub-source is estimated at ± 8 percent.

Underground degasification systems. MSHA reports which mines employ degasification systems and the type of degasification system used. MSHA, however, does not report methane liberated from degasification systems and coal mines are not required to report this data. Some coal mines have provided EPA with data on methane liberated. For other mines, EPA has estimated methane liberated based on the type of degasification system employed. Thus, for those mines that have provided data, the uncertainty would be low, whereas for those mines where EPA estimated methane liberated, the uncertainty would be higher. Uncertainty in this sub-source is estimated at -20 percent to $+10$ percent.

Methane used at underground mines. As mentioned previously, all coal mines must report gas sales to state agencies responsible for monitoring gas production. While there is little uncertainty associated with the reported gas sales, there is uncertainty associated with the timing of recognizing the emission reduction. For coal mines that recover methane in advance of mining, the emission reduction is recognized in the year in which the coal seam is mined-through. Thus,

without knowing exactly what is happening at a particular coal mine, there would be uncertainty associated with estimating methane used. Uncertainty in this sub-source is estimated at ± 15 percent.

Surface mines. Previous studies have indicated that methane emissions from surface mines are likely to be from one to three times greater than the in-situ methane content of the coal. The methodology assumes a value of two times the in-situ content of the coal. An additional uncertainty, however, relates to the estimated average in-situ content for each basin. Uncertainty in this sub-source is estimated at ± 50 percent.

Post-mining emissions. The uncertainties relating to post-mining emissions are similar to those for surface mining emissions, as a similar methodology is used. Uncertainty in this sub-source is estimated at ± 50 percent.

6.1 DATA ATTRIBUTE RANKING SYSTEM (DARS) SCORES

DARS is a system for evaluating the quality of data used in an emission inventory. To develop a DARS score, one must evaluate the reliability of eight components of the emissions estimate. Four of the components are related to the activity level (e.g., the amount of coal mined). The other four components are related to the emission factor (e.g., the amount of methane emitted per unit of coal mined). For both the activity level and the emission factor, the four attributes evaluated are the measurement method, source specificity, spatial congruity, and temporal congruity. Each component is scored on a scale of zero to one, where one represents a high level of reliability. To derive the DARS score for a given estimation method, the activity level score is multiplied by the emission factor score for each of the four attributes, and the resulting products are averaged. The highest possible DARS composite score is one. A complete discussion of DARS may be found in Chapter 4 of Volume VI, *Quality Assurance Procedures*.

The DARS scores provided here are based on the use of the emission factors provided in this chapter, and activity data from the US government sources referenced in the various steps of the methodology. If a state uses state data sources for activity data, the state may wish to develop a DARS score based on the use of state data.

TABLE 4.6-1

DARS SCORES: CH₄ EMISSIONS FROM COAL PRODUCED FROM UNDERGROUND MINING

DARS Attribute Category	Emission Factor Attribute	Explanation	Activity Data Attribute	Explanation	Emission Score
Measurement	8	The majority of emissions (from ventilation) are measured quarterly at individual mines, but if quarterly measurements fall below a cutoff they are not recorded by MSHA (e.g., because the mine is not operating). Degassification emissions are sometimes deduced.	10	Emissions are measured quarterly at individual mines; no activity level is used in developing an estimate.	0.80
Source Specificity	10	The majority of emissions (from ventilation) are measured; degassification emissions are deduced based on mine-specific factors.	10	Emissions are measured quarterly at individual mines; no activity level is used in developing an estimate.	1.00
Spatial Congruity	10	The majority of emissions (from ventilation) are measured; degassification emissions are deduced based on mine-specific factors.	10	Emissions are measured quarterly at individual mines; no activity level is used in developing an estimate.	1.00
Temporal Congruity	10	Emissions are measured or estimated each year.	10	Emissions are measured quarterly at individual mines; no activity level is used in developing an estimate.	1.00
Composite Score					0.95

TABLE 4.6-2

DARS SCORES: CH₄ EMISSIONS FROM COAL PRODUCED FROM SURFACE MINING

DARS Attribute Category	Emission Factor Attribute	Explanation	Activity Data Attribute	Explanation	Emission Score
Measurement	2	The range of emission factors for each coal basin is based on in-situ methane content and expert judgment.	10	Data on coal production are used; direct continuous measurement of coal production is assumed.	0.20
Source Specificity	7	Separate emission factors were developed for each coal basin, but not for each coal seam. Variability is assumed to be low to moderate.	5	The activity measured (coal production) is somewhat correlated to the amount of methane emitted.	0.35
Spatial Congruity	7	The factors were developed for coal basins, which in general are larger than states. Variability within a coal basin is assumed to be moderate.	10	States use state-level activity data to estimate statewide emissions.	0.70
Temporal Congruity	9	The range of emission factors for each coal basin is based on expert judgment, not on measured emissions over a particular time frame. The emission factors probably do not vary significantly over the course of a year.	10	States use annual activity data to estimate annual emissions.	0.90
Composite Score					0.54

TABLE 4.6-3

DARS SCORES: POST-MINING CH₄ EMISSIONS FROM SURFACE AND UNDERGROUND MINING

DARS Attribute Category	Emission Factor Attribute	Explanation	Activity Data Attribute	Explanation	Emission Score
Measurement	2	The range of emission factors for each coal basin is based on in-situ methane content and expert judgment.	10	Data on coal production are used; direct continuous measurement of coal production is assumed.	0.20
Source Specificity	7	Separate emission factors were developed for each coal basin, but not for each coal seam. Variability is assumed to be low to moderate.	7	The activity measured (coal production) is highly correlated to the amount of methane emitted.	0.49
Spatial Congruity	7	The factors were developed for coal basins, which in general are larger than states. Variability within a coal basin is assumed to be moderate.	10	States use state-level activity data to estimate statewide emissions.	0.70
Temporal Congruity	9	The range of emission factors for each coal basin is based on expert judgment, not on measured emissions over a particular time frame. The emission factors probably do not vary significantly over the course of a year.	10	States use annual activity data to estimate annual emissions.	0.90
Composite Score					0.57

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